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Seismogenic Stress Field and Tectonics in East Asia

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Abstract

Focal mechanism solutions of 1652 earthquakes from 1918 to 1991 have been analyzed to investigate the tectonic stress field in East Asia. The earthquake generating stress in the East Asian continent is attributed to the relative movements of the Pacific, Philippine Sea, Indo-Australian and Eurasian plates.

The compressive stress due to the Himalayan collision between the Indo Australian and the Eurasian plates causes P-axes to lie in the NE-SW direction in the broad triangular region from the Himalayas to the Baikal region. An identical NW-SE tensile stress field exists in broad region from the Baikal zone to the Ryukyu trench due to back arc spreading and marginal sea formation in the East China and Japan Seas. Strike-slip faulting events dominate in the North China and its surroundings. This may be attributed to the compressive stress from the Japan trench and the Himalayas, and the tensile stress from the Ryukyu trench and East China Sea. A compressive stress in a WNW-ESE direction exists from the Taiwan collision zone to the eastern region of southern part of the North-South Seismic Belt of China (NSB) through South China. This may be due to the collision along the Longitudinal Valley fault in Taiwan and subduction along the Ryukyu trench.

1. Introduction

Two famous interplate seismic belts, i.e., the Mediterranean Sea-Indonesian seismic zone and the western part of the Circum-Pacific seismic zone, lie along the margins of East Asia. Moreover, many intraplate seismic zones are distributed between the tow large interplate seismic belts. Large shallow earthquakes occur frequently in the continent far away from the plate bundaries. Characteristics of regional seismicity and focal mechanism solutions in East Asia have been investigated and reported by Tapponnier and Molnar (1977), Oike (1984), Xu et al. (1989), Xu et al. (1987) and others. The deep seismic zones in the Japan Sea, the Ryukyu and Philippine trench, in the eastern margin of East Asia, are related to the subduction of the Pacific and Philippine Sea plates. The subduction of the western Pacific plate along the Japan trench influences the seismogenic stress of the East Asian continent (Oike and Huzita, 1988). In addition, the study of focal mechanism solutions indicated that a shear stress field exists over the region from North China to Southwest Japan through the Korean peninsula (Mikumo and Ishikawa, 1987). In and around the Taiwan region. the collision between the Eurasian and Philippine Sea plates occurs in the eastern coast region along a WNW-ESE direction and subduction in a N-S direction occurs in the northeastern sea region off Hualian (Xu, 1993b : Kao and Chen, 1991).

Earthquakes occurring within the East Asian continent are almost all shallow. Intermediate depth seismic zones appear only around the ends of the Himalayan Mountains. They are the Hindukush-Pamir region in the central Asia and Myanmar region in the southeast Asia (Chatelain et al., 1980, Ni and Barazangi, 1984). The velocity of relative northward crustal motion is 1.5 cm/yr in and around the Pamir region and the Altal mountains, as estimated from the measurement of local surface deformations (Kakkuri and Konttinen, 1986). In the Tibetan plateau and the Tianshan region, the vertical crustal movement due to the collision between the Eurasian and Indo-Australian plates is the most obvious characteristic (Ying et al., 1986, Valdiya, 1981). The crustal deformation also appears in the Baikal region where the angular rate of rotation of Eurasian and Amurian plates is about 1.10×10^{-7} deg/yr estimated from the amount of Baikal opening (Zonenshain and Savostin, 1981).

The geodynamics of seismic activity in North China may be affected by the motion of the Pacific Ocean plate (Shimazaki, 1984) and by the vertical forces from the inner part of the earth (Zhen et al., 1985). In the continental part of China, the seismotectonics and seismic activity are caused by the collision between the Indo-Australian and Eurasian plates (Molnar and Tapponnier, 1977). They experimentally simulated the evolution of large strike-slip faults in East Asia and suggested that the northward movement of the Indo-Australian plate controlled the tectonic stress field in the East Asian continent (Peltzer and Tapponnier, 1988).

Moreover, the tensile geotectonic activity revealed in the Shanxi graben of China,

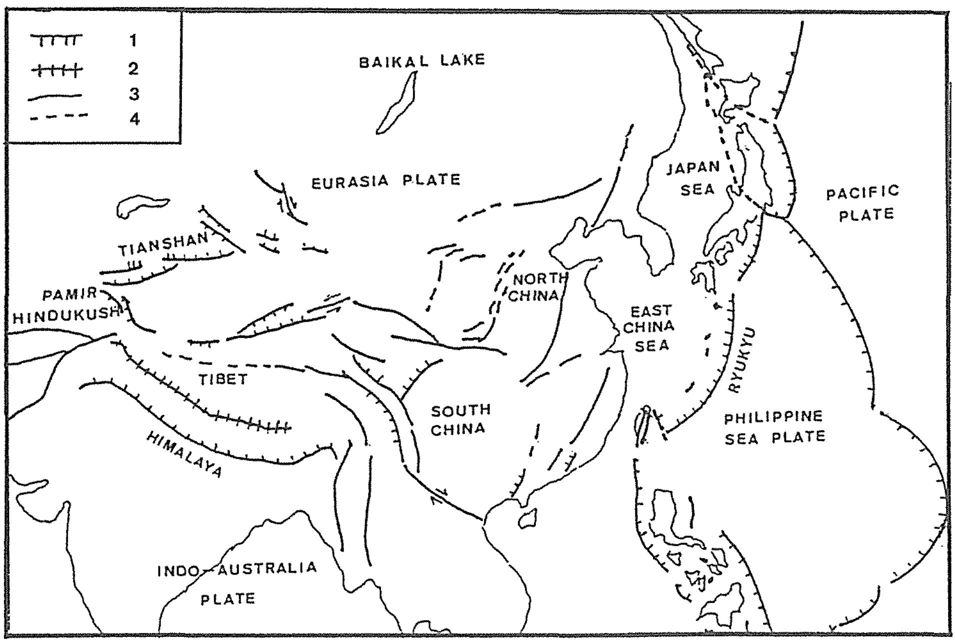


Fig. 1. Tectonics map in East Asia modified from the map by Huzita, 1984. 1: convergent boundary or reverse fault; 2: suture zone; 3: fault; 4: hidden fault.

the Baikal region and the higher area of the Tibetan plateau of the East Asian continent. Although the results of mantle convection modeling indicate that the tensile stress caused by the upward mantle convection under the crust might act on the Tibetan region and the Shanxi graben (Liu, 1978), this is an question not solved why the formation of tensile stress field in these regions by the surrounding plate moving.

In order to clarify the intraplate stress field, it is necessary to study the dynamic characteristics of stress field in East Asia as shown in Fig. 1 based on mechanism solutions of earthquakes. In this paper, characteristics of focal mechanism solutions and regional stress field in East Asia will be studied at first. Then, some fundamental problems involving the tectonic force system and its relation to stress fields over East Asia are investigated.

2. Data and Methods of Analyses

Focal mechanism solutions from 1369 shallow earthquakes and 283 intermdiate-depth and deep earthquakes were used in this study. Solutions partly determined by Xu et al. (1988, 1992, and 1993a) referred to the Bulletin of the International Seismological Center (ISC). CMT solutions for earthquakes with magnitude greater than 5.0 from 1977 to 1987 were also used in this study (for example, Dziewonski et al., 1983 (a) and 1983 (b)).

The status of seismogenic stress field in East Asia was investigated mainly through by examining the orientation of the principal stress of compressive axis (P-axis) and tensile axis (T-axis), and the plunges of P- and T-axis of mechanism solutions of earthquakes. The regional geodynamics was analyzed on the basis of the results derived from mechanism solutions. In order to understand the relative movement among plates and the properties of stress field of seismic zones, the profiles of P-axes and T-axes distribution were used to identify the system of stress field and regimes of plate motion : collision and subduction.

3. Characteristics of Seismogenic Stress Field

The distributions of horizontal projections of P-axes and T-axes of mechanism solutions of shallow (0–100 km) earthquakes in the period from 1918 to 1990 in East Asia are shown in Fig. 2 and Fig. 3, respectively. In order to clarify distribution characteristics of earthquake faulting types, the earthquakes were classified into three faulting types. If the plunge angle of P-axis for an earthquake is greater than that of its T-axis, and if it is greater than or equal to 45°, the earthquake is classified as a normal faulting type earthquake. In the same way, if the plunge angle of T-axis is greater than that of its P-axis, and if it is greater than or equal to 45°, the earthquake is considered a reverse fault. If both of plunge angles of P- and T-axes are less than 45°, the earthquake is classified as a strike-slip fault. The distribution for the normal, reverse and the strike-slip faulting type events is shown in Fig. 4.

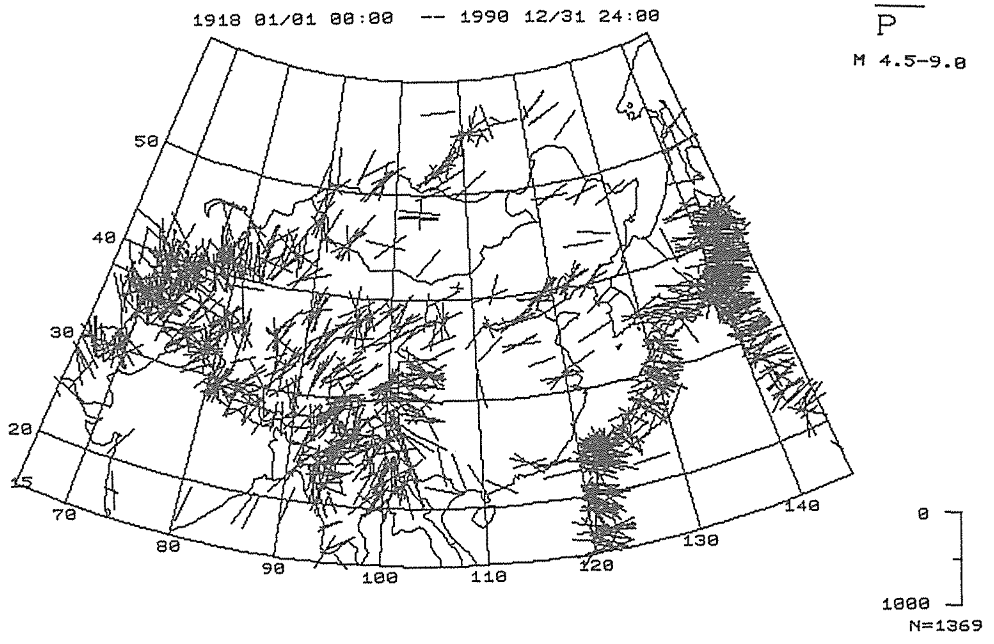


Fig. 2. Horizontal projection of compressive axes (P-axes) of mechanism solutions of shallow (0–100 km) earthquakes in East Asia.

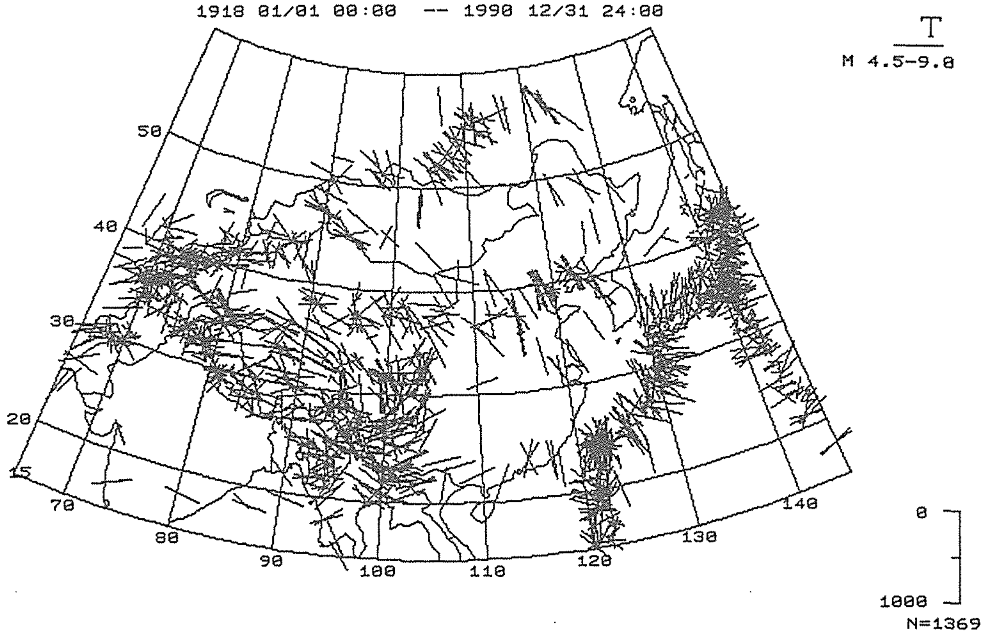


Fig. 3. Horizontal projection of extensional axes (T-axes) of mechanism solutions of shallow (0–100 km) events in East Asia.

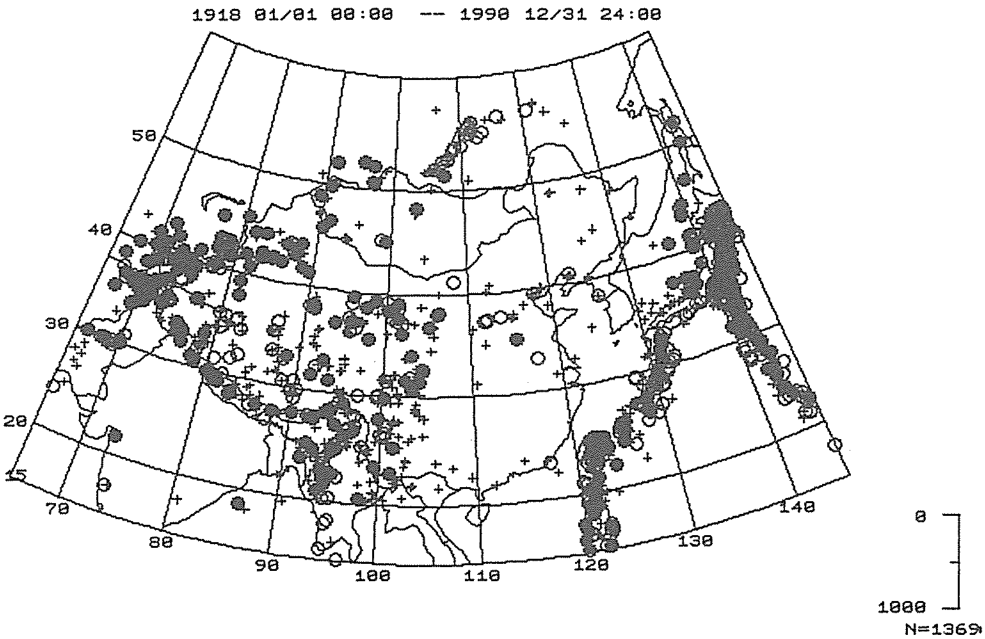


Fig. 4. Distrbutions of the normal, reverse and strike-slip faulting events in East Asia. Open circles, closed circles and crosses correspond to normal, reverse and strike-slip faulting events, respectively.

3.1. From the Himalayan Collision Zone to the Baikal Zone

Based on the epicentral distribution and the characteristics of stress field, a broad sctive seismic region seems to be confirmed (Fig. 2, Fig. 3 and Fig. 4), from the Himalayan mountains to the Baikal lake. It includes the Tibetan platan, the Tianshan mountains and the Altay mountains located in its northwestern boundary, and the western region of the southern part of the North-South Seismic Belt of China (NSB) in its eastern boundary. Many earthquakes occur in this broad triangle-shepe region. The Himalayan mountains extend from the Hindukush-Pamir region to the Myanmar region over thousands kilometers along the boundary between the Eurasian and the Indo-Australian plates. Earthquakes occurring in the region from the Himalayas to the Baikal generally are shallow crustal ones. In the Hindukush-Pamir and Myanmar regions, however, intermediate depth earthquakes occur.

In the Himalayan mountains, most of P-axes of focal mechanism solutions are oriented NE-SW or NNE-SSW and almost perpendicular to the Himalayan arc (Fig. 2). T-axes are along this arc as shown in Fig. 3 In the wide triangle-shape region from the Himalayan mountains to the Baikal region, most of horizontal projections of P-axes are in the NE-SW direction. Especially, in the Tibetan plateau and the western region of the NSB, P-axes show identical distribution in the NE-SW direction. It is consistent with that in Himalayan mountains (Fig. 2).

In the western intermediate-depth seismic zone of the Pamir-Hindukush plateau and South Tianshan regions, P-axes of shallow earthquakes are in the NNW-SSE diection. P-axes, however, are in the NE-SW direction in the Kashmir and Himalayan

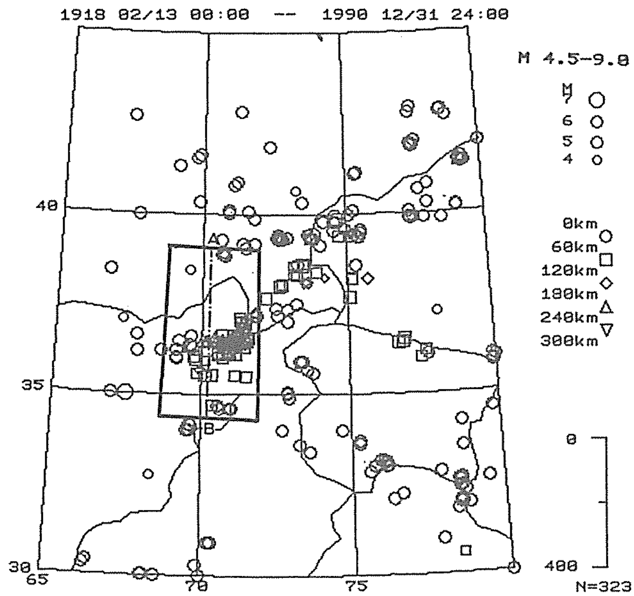


Fig. 5. Epicentral distribution of earthquakes in the Hindukush-Pamir region. Profile along AB line is shown in Fig. 6.

regions located in the east to the intermediate-depth seismic zone. T-axes have small horizontal components in the NE-SW direction in the former two regions. T-axes horizonatlly lie in the NW-SE direction in the Kashmir region. Fig. 6 shows the longitudinal profiles of P- and T-axes along AB line in Fig. 5. P-axes orient in the N-S direction alsong the intermediate depth seismic segment and T-axes are perpendicular to sinking intermediate depth seismic segment.

In the Myanmar region, P-axes of focal mechanism solutions are dominantly in the NE-SW direction. Fig. 7(b) shows the profiles of P- and T-axes in the intermediate-depth seismic zone along the AB line Fig. 7(a). As shown in Fig. 7(b), a Benioff zone near E-W direction reveals there down to 148 km deep. Its dip angle is about 40°. Almost T-axes are along the down-dip direction and P-axes are perpendicular to the down-dip direction, which are similar to that in the Hindukush-Pamir intermediate-depth seismic zone.

Fig. 8 shows the epicentral distribution of earthquakes in the western region of East Asia. Three vertical profiles of P- and T-axes along lines AB, CD and EF in Fig. 8 are shown in Fig. 9(a), (b) and (c), which are from the Hindukush-Pamir region, the central part of Himalaya and the southernend of the NSB to the Baikal region, respectively. Many earthquakes occur in the zone from the Hindukush-Pamir to the Baikal region through the Tianshan and the Altay mountains. It is called the Hindukush-Baikal seismic zone here. P-axes are oriented NW-SE or NE-SW in the Hindukush-Baikal region. As shown in Fig. 9(a), P-axes of shallow earthquakes are perallel to surface in the region from the Hindukush to the Eastern Sayan mountains in Russia. Corresponeingly, T-axes are perpendiclar to the surface there. The vertical component of P-axes increases gradually passing the Sayan mountain and P-axes turn

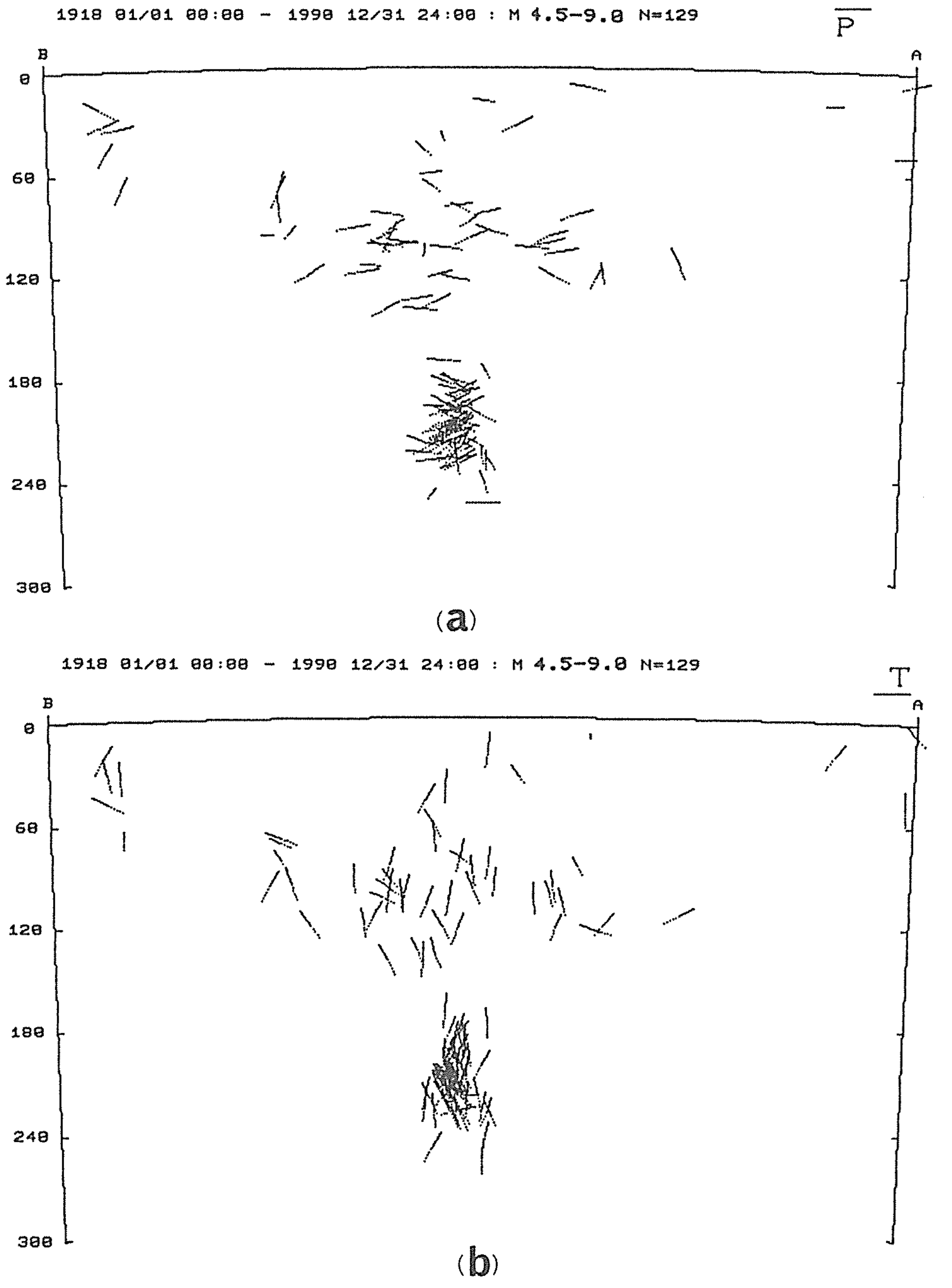
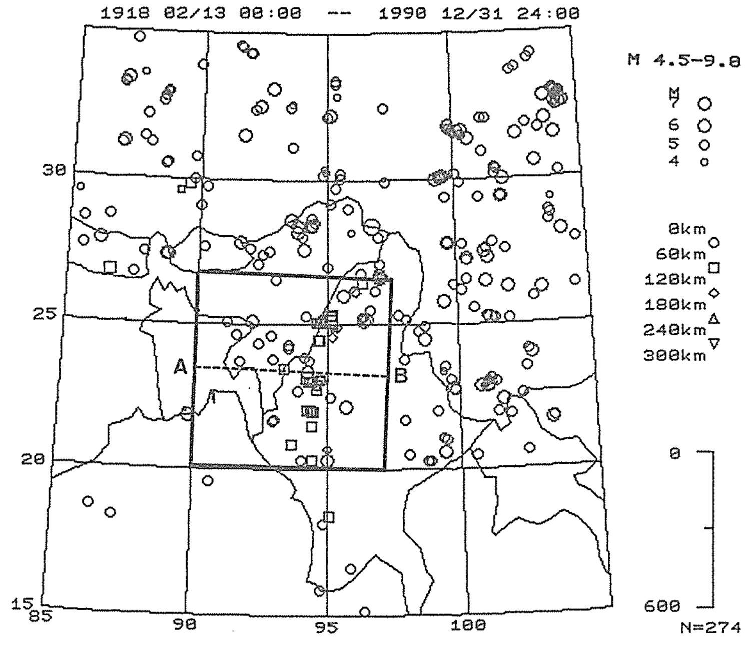
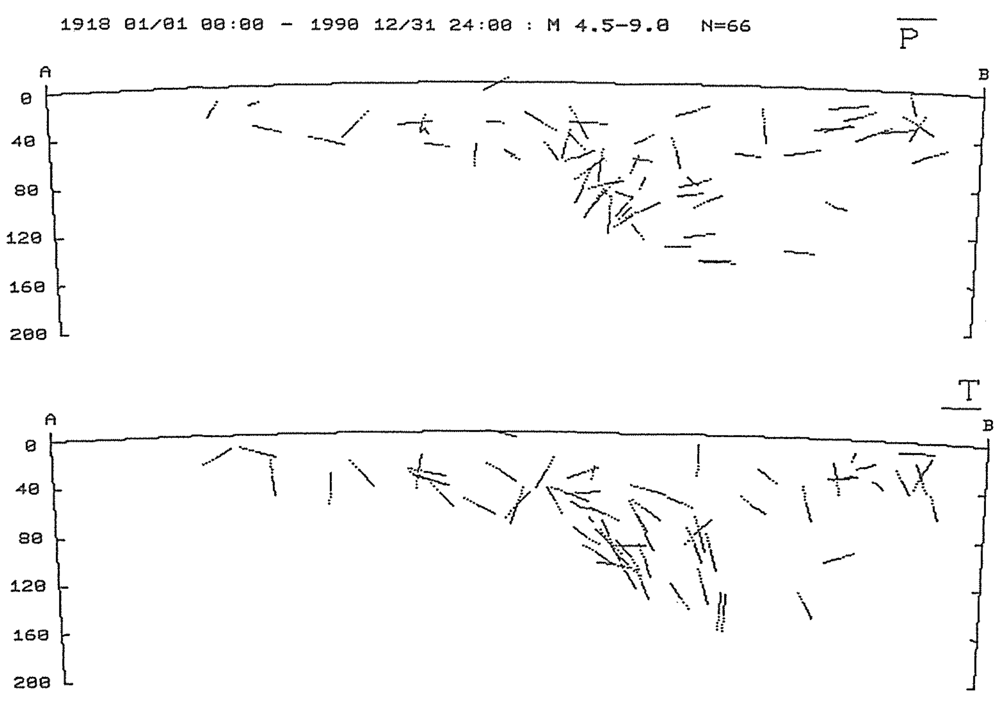


Fig. 6. Profiles of the distribution of P- (a) and T-axes (b) in the Hindukush -Pamir region along AB in Fig. 5.

to perpendicular to the surface in the Baikal region. The horizontal component of T-axes increases gradually and T-axes turn to parallel to the surface in the Baikal region. Fig. 9(b) shows that in the Himalayan arc, P-axes are parallel and T-axes are perpendicular to the surface, which are characteristics of the collision zones. P-axes



(a)



(b)

Fig. 7. (a) Epicentral distrbution of earthquakes in the Myanmar region. (b) profiles of distribution of P- and T-axes along AB in Fig. 7(a) in the Myanmar region.

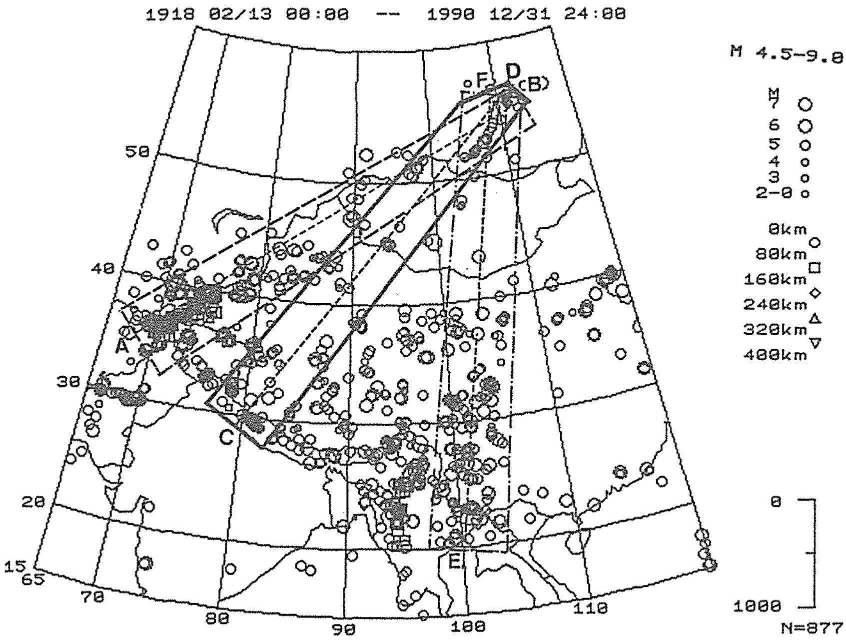


Fig. 8. Epicentral distrbution of earthquakes in the western region of East Asia. Lines AB, CD and EF are vertical profiles, which are from the Hindukush-Pamir region to the Baikal region (AB), from the central part of the Himalayan arc to the Bikal region (CD) and from the southernend of the North-South Seismic Belt to the Baikal region (EF).

turn to perpendicular to surface and T-axes turn to parallel to the surface in the central area of the Tibetan plateau, which forms a normal faulting type seismic zone there. In the region to northeast of the Tibetan plateau, P-axes are parallel and T-axes are perpendicular to the surface. It shows that the compressive and tensile stress control the regional features from the central part of the Himalayan arc to the Baikal region, alternately. Fig. 9(c) shows the profile of distributions of P-and T-axes along EF line in Fing. 8. It indicates that the compressive and tensile stresses control stress field and the strike-slip type earthqyakes occur in the NSB.

Many reverse faulting type events occur in the boundary regions around the Tibetan plateau, expect in the southern part of the NBS (Fig. 10). Most of earthquakes in the high area of the Tibetan plateau are normal fault or the combination of normal and strike-slip faulting type as shown in Fig. 10. Fig. 3 and Fig. 10 show that the tensile stress in the E-W or WNW-ESE direction dominate the seismo-tectonics in the high area of the Tibetan plateau. The orientations of P-axes in the western region of southern part of the NSB are mainly in the N-S or NE-SW directions and the P-axes in the eastern region are in the NW-SE direction. Events there are caused by strike slip faults.

Reverse and strike-slip faulting type events occur in the northern region to the Tibetan plateau. The compressive stress in near N-S and NE-SW control the earthquake generating stress field as same as that in the Himalayan mountains.

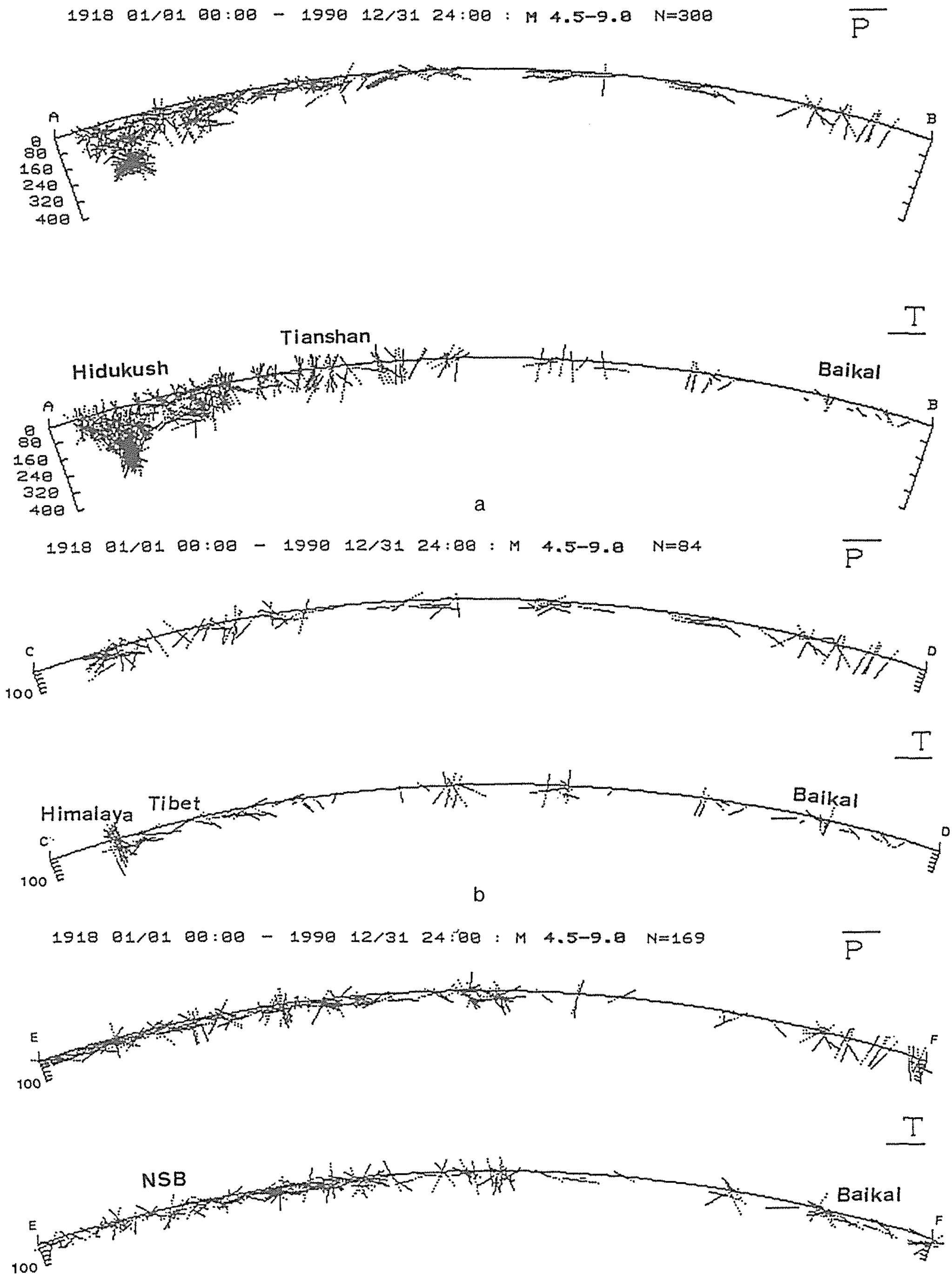


Fig. 9. (a) Profiles of the distribution of P- and T-axes slong AB in Fig. 8 from the Hindukush-Pamir to Baikal region. (b) Profile distributions of P- and T-axes along CD in Fig. 8 from the central part of the Himalayan arc to Baikal region. (c) Profile distrbutions of P- and T-axes along EF in Fig. 8 from the southernend of the North South Seismic Belt to Baikal region.

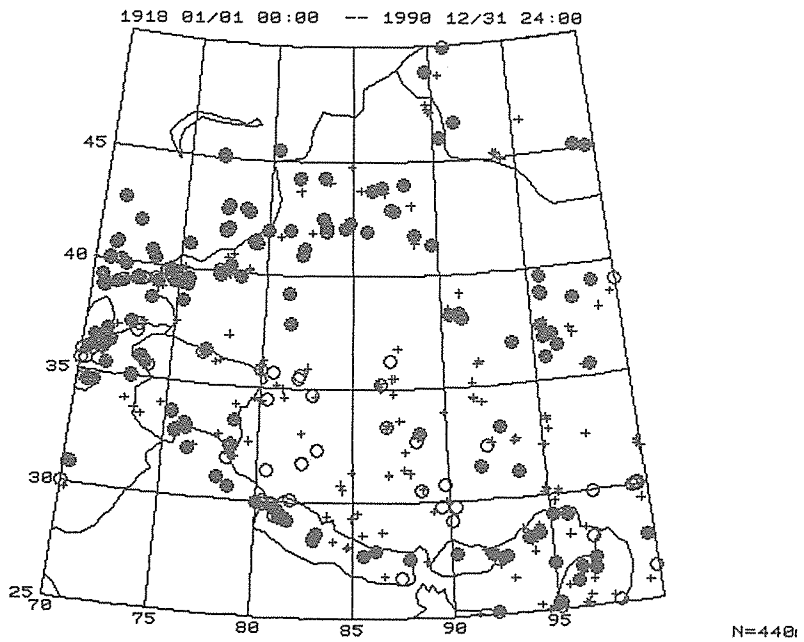


Fig. 10. Distrbutions of the normal, reverse and strike-slip faulting earthquakes in and around Tibetan plateau. Open circles, closed circles and crosses correspond to normal, reverse and strike-slip faulting respectively.

3.2. Form the Baikal Zone to the Ryukyu Trench

A characteristic for stress field in East Asia as shown in Fig. 3 is that T-axes are oriented NW-SE in the wide region between the Baikal lake and Ryukyu trench through the North China and East China Sea. It implies that a tensile stress field exists in this broad region with width of thousands kilometers.

Fig. 11 shows the distribution of the normal, reverse and strike-slip faulting events (0–100 km) in the Ryukyu trench. Most of reverse faulting events distributed along the Ryukyu trench. The compressive axes in the NW-SE direction are dominant in the Ryukyu arc region. Strike-slip and normal faultin events occur in the back-arc region and normal faulting events occur in the before-arc region.

Epicentral distribution of earthquakes in the eastern region of East Asia is shown in Fig. 12. Fig. 13 shows the profile distributions of P- and T-axes along Line AB from the Ryukyu trench to the Baikal region as shown in Fig. 12. It indicates that T-axes are parallel to the surface from the back-arc of the Ryukyu trench to the Baikal region and a consistent tensile stress field exists there. P-axes are perpendicular to the surface in the Baikal region (as an normal faulting seismic zone) and partly in the North China as shown in Fig. 13. The tensile stress field exists there.

In the Western Pacific seismic belt, P-axes mechanism solution of earthquakes in Southwest Japan (a continental seismic zone) are quite consistent with those in Japan trench (a interplate seismic zone). They are mainly in the E-W or WNW-ESE direction. P-axes are oriented NE-SW or ENE-WSW in North China. P-axes are

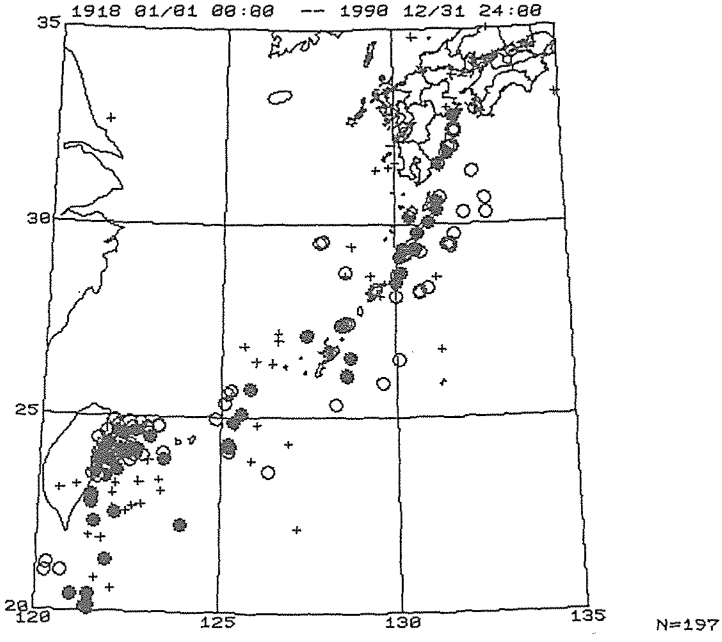


Fig. 11. Distributions of the normal, reverse and strike-silp faulting earthquakes (0–100 km) in the Ryukyu trench. Open circles, closed circles and crosses correspond to normal, reverse and strike-slip faulting earthquakes, respectively.

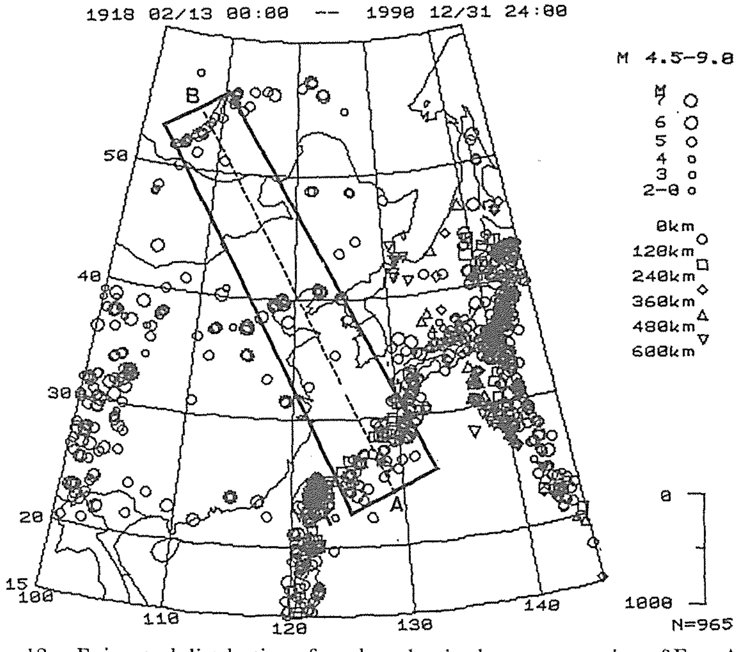


Fig. 12. Epicentral distrbution of earthquakes in the eastern region of East Asia. Line AB is vertical profile from the Ryukyu trench to Baikal region.

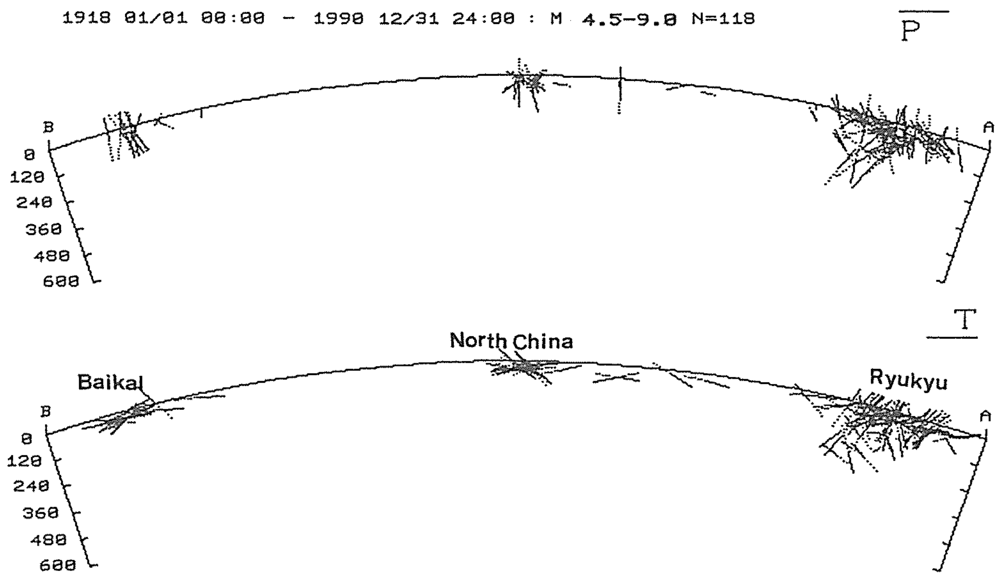


Fig. 13. Profile distributions of P- and T-axes along AB in Fig. 12.

roughly in concord in the region between the Japan trench and North China through the Korean peninsula. The consisten compressive stress field seems to superposed on the large scale of homgeneous tensile stress field. Strike-slip faulting events predominate in Mongolia, North China, East China and the Korean penisula.

3.3. From Taiwan Collision Zone to the Southern Part of the NSB

This region is from the collision zone along the eastern coast in Taiwan to the eastern region of the southern part of the NSB through South China.

In the Taiwan and Luzon regions, P-axes of earthquake mechanism solutions are oriented NW-SE with small plunge angles. The occurrence of events in this region is dominated by the compressive force in the WNW-ESE direction. Most of earthquakes occur there as reverse fault. In the northeastern area off Taiwan, P-axes of mechanism solutions of shallow earthquakcs are near vertical direction and T-axes are oriented N-S. The tensile stress is principal and many normal faulting events occur there. The difference of subregional characteristice indicate that the seismo-tectonic condition is complex in the Taiwan region.

The seismic activity is low in South China. Only a few events concentrate in the Southeastern Coast seismic zone of China, whose P-axes are approximately oriented WNW-ESE. In the eastern region of the southen part of the NSB, P- and T-axes of mechamism solutions approximate those in South China where the former and the latter are oriented NW-SE and NE-SW, respectively (Fig. 2 and Fig. 3).

On the whole, P-axes of mechanism solutions approximate the NW-SE direction in the wide region from the Taiwan collision zone to the eastern region of the southern part of the NSB through South China. It implies that a compressive stress in the NW-SE direction contrls the seismicity in this region, although the reverse fault in the Taiwan collision zone and the Philippine Sea trench changes into the strike-slip fault in South China and the southern part of the NSB.

4. Discussion

According to the mechanism solutions, the relative movements between the Pacific Ocean, Philippine Sea, Indo-Australian plates and the Eurasian plate not only control the genesis of interplate earthquales, but also control those of the intraplate earthquakes in the continent of East Asia. Some regional characteristics of seismogenic stress filed in the inner part of East Asian continent may be attribyted to the relative movements of the crustal blocks.

4.1. Consistent Compression from the Himalayan Collision Zone to the Baikal Zone

The consistent compressive force derived from the directions of P-axes of focal mechanism solutions is predominately in the NE-SW or the NNE-SSW direction over the wide region from the Himalayan collision zone to the Baikal. Such a seismogenic stress field may strongly be attributed to the collision activity at the boundary between the Indo-Australian and Eurasian plates.

The Indo-Australian plate is moving towards the Eurasian plate at rate of 4.5 cm/yr and causes the compressive stress in the NNE-SSW or the NE-SW direction in the Himalayas (Minstrer et al., 1974). The Indian peninsular encountered with the Eurasian landmass during the Miocene and the Pliocene periods (Deway and Bird, 1970). The tectonic force from the collision causes the shallow block to the north of the Himalayas to uprise. It has created Himalayan orogenic movements and the high Tibetan plateau since the period of Late Cenozoic (30 Ma ago). This compression has influenced over the Tianshan mountains and the west Mongolia region (Otsuki, 1985). The crustal deformation in this wide region is very conspicuous. P-axes of focal mechanism solutions obtained in this study are perpendicular to the Himalayan arc and T-axes are along this arc in all sections (Fig. 2, Fig. 3). The strong northward moovement of the Indo-Australian plate towards the Eurasian plate causes the distribution of the compressive stress field in the NE-SW direction from the Himalayan collision zone to the Baikal region through West China.

The direction of compressive stress in the front of intermediate-depth earthquake zone under the eastern Hindukush region in the Hindukush-Pamir region (Fig. 5 and Fig. 6) is 174° near N-S direction. This direction approximates that of relative movement there between two plates. Based on distributions of earthquakes and stress field along intermedite-depth seismic zone, it can thougth that the Indo-Australian plate subducts beneath the Eurasian plate there. A down-dip tensile stress field exists within the slab where P-axes are perpendicular to the slab and T-axes are parallel to the dip direction of the slab. The compression with the N-S direction in the slab and the lateral ejection in the crust can be attributed to the northward subduction. The subducting slab wedges into the continent, which leads the lateral ejection of P-axes of shallow crustal earthquakes. P-axes turn to NNW-SSE direction in the western Hindukush, the Pamir and the South Tianshan region located to the north and west of the subduction zone, and P-axes turn to the NE-SW direction in the western Himalayan and Kashmir regions located to the east of the subduction zone (Xu et al., 1992).

In the Myanmar region, the plate motion of the Indian peninsular changed its direction from NE-SW in the central segment of the Himalayas to near E-W here. The Indo-Australian plate subducts beneath the East Asian continent and creates the down-dip tensile stress field acted on the slab like that in the Hindukush -Pamir region (Fig. 7) (Verma amd Kumar, 1987, Chen and Molnar, 1990).

Reverse faulting type events occur in the Himalayas, Tianshan, Altay and the Eastern Sayan mountains which are located on the northwestern and southern boundaries of the large triangle-shape region. Strike-slip faulting events occur in the southern part of the NSB of its eastern boundary (Fig. 4).

Normal faulting events occur in the high Tibetan plateau, in which the crustal thickness are more than 68 km and the Bouguer anomaly is –500 mgal (Feng, 1985). Such special geographic characteristics of high Tibetan plateau may be correlated to the normal fault events occur here. The weigt of high plateau and the buoyancy acting on the bottom of the crust from mantle create an additional vertical compressive stress. When the vertical stress becomes greater than the maximum horizontal compressive stress in near N-S direction due to the collsison at the Himalayas, the relaxation of topography or the thinning of crust with normal faulting occur. Extensional geological tectonic activities such as the extensional crevices (Molnar and Tapponnier, 1987) and the extensional (N-S) graben called as "boudinage structure" in the Tibetan plateau (Froidevaux and Ricard, 1987) are consistent with the results in this study. On the other viewpoint, in the northern margin of the normal faulting zone, a volcanic eruption took place at the south Yutian county of Xinjiang province on October 27, 1951 (Tong et al., 1982). Volcanic eruption is related to the upward mantle convection. The upward movement of mantle convection can also generate the large tensile stress.

Only the horizontal compressive forces act in the lower places surrounding the high plateau. Therefore, the reverse and strike-slip faulting earthquakes occur in its surroundings. In the region north to the Qilian mountains and Mongolia, the reverse faulting or strike-slip faulting events with compressive forces near N-S to NE-SW direction dominate the earthquake generating stress. It indicates that this wide area is compressed by the neighboring southern crustal blocks. In the northern margins of the Chaidamu Basin and the Tarim Basin, P-axes of solutions are in the NW-SE direction and T-axes are in the E-W direction. It may be because that many microplates exist there.

The profiles of distribution of P- and T-axes along a long seisimc belt from Hindukush-Pamir region to the Baikal region through the Tianshan, Altay mountains and West Mongolia show the change and attenuation of the compressive stress with the distance far away from the Himalayan collision zone (Fig. 8, Fig. 9(a)). The strong compressive force from the Himalayan collision zone controls the regional features from the Himalayas to the Eastern Sayan mountains in Russia. In the region from the Eastern Sayan mountains to the Baikal lake, however, the compressive stress is attenuated and the tensile stress is dominant there. Such systematic changes of P- and T-axes indicate that the crustal stress field changes regularly from domination of compression to domination of extension in the seismic zone of the Hindukush-Baikal. The domination of the compressive stress alternates with that of the tensile stress in the profile distrbutions along CD line (Fig. 8 and Fig. 9(b)). It can be attributed to the opening Tibetan plate and the Baikal. In the large triangle-shape region, the strong compressive stress field from the Himalayan collision zone exists in the Himalayan arc and the western boundary i.e. the seismic zone of the Hindukush-Baikal. The strong compressive stress becomes weak from west to east. In the eastern boundary i.e.the NSB, the compressive stress and the tensile stress together control the seismic activity, as shown in profile along EF line (Fig. 8 and Fig. 9(c)). So strike-slip faulting events dominatly occur.

4.2. Consistent Extension from Baikal Zone to the Ryukyu Trench

T-axes are almost consistently in the NW-SE direction in the region from the Baikal zone to Ryukyu trench. Such a consistent tensile stress field in this broad region may be attributed to spreading activities in the back arc regions of the Ryukyu trench, East China Sea and Japan Sea due to the subduction of the philippine Sea plate and the Pacific Ocean plate.

Philippine Sea plate is moving northwestward at the rate of 7.0 cm/yr in the Ryukyu trench (Seno, 1977). Since Quaternary, the extensional stress direction has been perpendicular to the Ryukyu trench. The crustal extensions occur in the NNW-SSE direction taking the trough as an axis in the southern Okinawa trough (Furukawa, 1991). These results are consistent with those in this study that the trough is the normal faulting seismic zone. Moreover, the expansion occurs in the Jaapn Sea and the East China Sea making marginal seas. It may be because that the mantle convection due to the slab motion generates the tensile stress (Toksoz and Hsui, 1978). On the other hand, perhaps, the compression from subduction and the resistance due to the molten slab generated tensile stress over the slab as large as 1,000 bars (Ida, 1978). The tensile stress can cause the crustal expansion to form the marginal sea like Japan Sea and East China Sea. The function of the subduction perhaps extends into the continent. The volcano ctivities in the northeastern region of China are related to the subduction from the Japan trench, too. It implies that the mantle convection occurs under the crust of the northeastern region of China.

Such a tensile stress field contributes to the occurence of the strike-slip faulting events in the broad region, and the normal faulting events in Baikal. It may contributes also to the Baikal opening in the NW- SE direction. The southeastward moving influenced over the tectonic crustal motions and the seismogenic stress field in the Amurian block and North China block (Zonenshain and Savostin, 1981).

The westward compression in Japan Island due to the subduction has begun since Quaternary (Ma, 1986). The compression from subductions of the Pacific Ocean plate in the western part of Circum-Pacific seismic belt and the Philippine Sea plate in the Ryukyu trench have influenced the tectonic motions and the seismic activity in the Amurian block, North China, Korean peninsula and the Wide sea region between China and Japan too. It generates compressive component of seismogenic stress field in those regions. The horizontal stress difference between the compression due to the subductions and the tensile due to the spreading in the back arc and marginal sea cause many large strike-slip faulting earthquakes in the regions of the East Asian continent, for example, the 1976 M7.8 Tangshan earthquake occurred in the North China. Crustal movement there mainly causes strike-slip faults.

4.3. Consistent Compression from Taiwan Collsion Zone to the Eastern Region of the Southern Part of the NSB

Based on the earthquake mechanism solutions, it can be derived that a consistent compressive stress field in the WNW-ESE or in the NW-SE direction exists from the Taiwan collision zone to the eastern region of the southern part of the NSB through South China.

The Philippine Sea plate turns the motion from subduction along the Ryukyu trench into the collision along the Longitudinal Valley Fault in the eastern coast region of Taiwan (Xu, 1993b, Barrier and Angelier, 1986). The strong collision has caused the violent orogenic movement. The mountains in the central part of Taiwan uplift as high as 3952 m. The eastern coast region in Taiwan has risen at the rate 5 mm/yr (Ma, 1986). The average direction of P-axes in the central and southern region of Taiwan almost was consistent with the WNW-ESE direction of relative movement between the Philippine Sea and the Eurasian plates (Lin et al., 1985). Many reverse faulting events occur in the southeastern region of Taiwan and their P-axes nearly are perpendicular to the Coastal Range as a typical collision zone.

South China block is a stable geological structural block. Only a few strike slip faulting earthquakes occur there, whose P-axes are in the NW-SE direction. They coincide well with those in the east and west vicinities,Taiwan collision zone and the eastern region of the southern part of the NSB. Seismicity in the South China is related to the relative movement of Philippine Sea plate, like seismicity in the Taiwan and the Philippine Sea regions (Oike, 1991). The collision in Taiwan region has influenced the tectonic movement of the South China block over the Taiwan straits (Xu, 1993a). It may cause P-axes in South China to be in the NW-SE direction, coinciding with those in the Taiwan collision zone.

Earthquakes in Taiwan collision zone are interplate ones, and they are caused by relative plate movement. Therefore, the earthquake generating stress in South China is possibly caused by the transmission of tectonic forces from the subduction of the Philippine Sea plate along the Ryukyu trench and the collision beteen the Philippine Sea and the Eurasian plates at Taiwan island.

The South China block encounters the Tibetan plateau with northeastward movement in the southern part of the NSB. It reduces the rate of the eastward movement of the Tibetan block. The average directions of P-axes in the western and eastern regions of the southern part of the NSB are oriented NE-SW and NW-SE, respectively (Xu, 1993a). It suggests on the view of geodynamics, that the seismogenetic stress field in the eastern region of the southern part of the NSB is same as its east vicinity, i.e. South china, atributed to the tectonic force originating from the movement of the Philippine Sea plate in the Taiwan region and the Ryukyu trench.

5. Conclusions

The geodynamic characteristics of seismogenic stress field in East Asia can be concluded as follows and shown in Fig. 14.

1) Earthquake generating stress field in the East Asian continent is attributed to the relative movements of the Pacific Ocean, Philippine Sea, Indo-Australian and the Eurasian plates. The tectonic force due to the relative movements of plates around East Asia transmitted in the Asian continent as the compressive or tensile stress, they caused varied earthquakes with the geological background conditions. The regional stress field and the earthquake faulting types are complicated owing to the relative movements among many crustal blocks.

2) The compressive stress field due to the Himalayan collision between the Indo Australian and Eurasian plates causes P-axes to lie in the NE-SW direction in broad region from the Himalayas to the Baikal lake consistently.

Reverse faulting events occur along the boundaries of this large triangle-shape region except in the east. The compression becomes weak with the distance from the collision zones away and the strike-slip faulting type events predominate in other continental region. The 5 km high Tibetan plateau is a region of normal faulting. This may be caused by the additional vertical stress field due to the weight of high plateau and the buoyancy of the lower crust.

3) An identical NW-SE tensile stress field exists in broad region from the Baikal zone to the Ryukyu trench through Noth China due to back-arc spreading and marginal

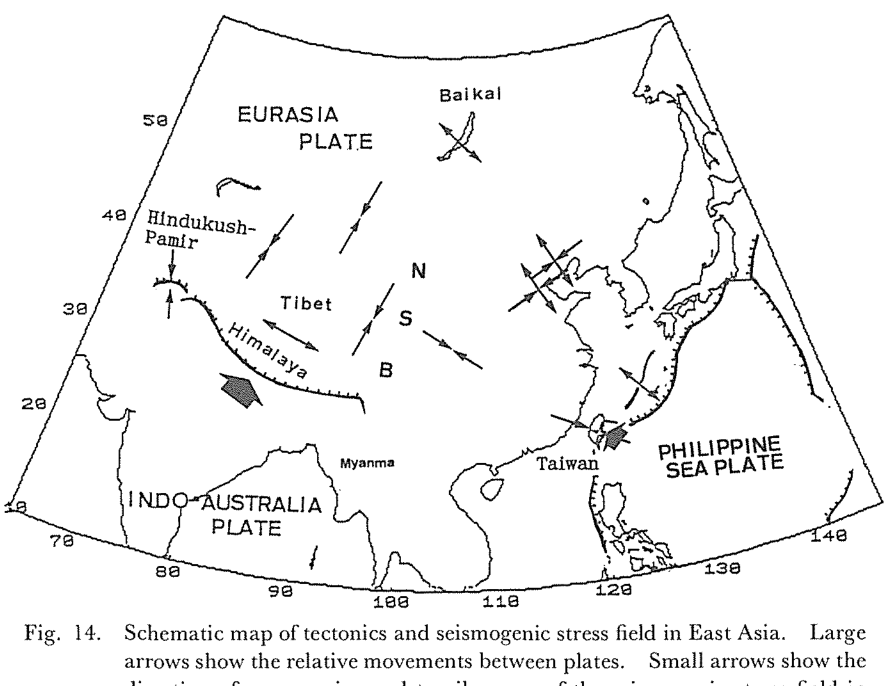


Fig. 14. Schematic map of tectonics and seismogenic stress field in East Asia. Large arrows show the relative movements between plates. Small arrows show the direction of compressive and tensile areas of the seismogenic stress field in East Asia. NSB means the North-South Seismic Belt of China.

sea formation in the East China and Japan Seas.

4) Strike-slip faulting events dominate in North China and its surroundings. This may be attributed to the compressive stress from the Japan trench and Himalayas, and the tensile stress from the Ryukyu trench and East China Sea.

5) An compressive stress in a NW-SE direction exists from the Taiwan collision zone to the eastern region of the southern part of the NSB through South China. This is attributed to the collision along the Longitudinal Valley fault in Taiwan and the subduction along the Ryukyu trench between the Philippine Sea and Eurasian plates.

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